FINAL REPORT

19980166

PRECISION FARMING - NORTHEAST AGRICULTURAL RESEARCH FOUNDATION

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Agri-Food Innovation Fund
Final Report
Project #98000166

Precision Farming – Northeast Agriculture Research Foundation

January 29, 2003

Summary

The conclusion of this project is that even the finest soil sampling method is of no value if the soil analytical approach and subsequent fertilizer recommendations do not predict the correct application rates to any degree of reliability. Current nitrogen recommendations from soil test laboratories in western Canada are based entirely on residual nitrate-nitrogen and use broad geographic predictions for the release of mineralizable nitrogen, they do not take into account the release of mineralizable nitrogen from the soil sample that was submitted. Until a reliable prediction of this release is integrated into the recommendations systems, nitrogen fertilizer recommendations from existing soil test laboratory databases are not adequate to select the economically optimum rate of nutrient to apply for variable rate nitrogen applications.

1. Study Objectives

The objective of this 4 year project (1999 to 2002) was to investigate four soil sampling strategies to determine which method provided the best fertility recommendations for developing prescriptions for variable rate fertilization (VRF) of nitrogen. By implementing the soil testing studies and working with commercial service providers, NARF was hoping to assist farmers in the implementation of VRF.

2. Background

This study was initiated in 1999. NARF had a strong contingent of board members with yield mapping systems and rate controllers. NARF had a copy of SSToolbox™, arguably one of the finest Geographic Information Systems (GIS) available. It can be used for the import and analysis of satellite imagery, yield maps, variable rate application maps, soil testing locations and data, and any other relevant geo-referenced data. NARF also had the staff and required equipment to implement a geo-referenced soil sampling program. Cargill agreed to perform their management zoning procedure on 3 fields, develop the prescription, and provide the controller interface in order to apply the prescriptions. The only nutrient that was field tested in this study was

nitrogen, although data was collected on the other nutrients. All investigations were field-scale. NARF began the study assuming that service providers would provide a VRF implementation to the farmers. Ironically, it was a farmer that became the service provider for VRF and his work allowed NARF to continue test soil testing techniques in 2001 and 2002.

3. Project Activities

The three farm cooperators in this project in 1999 were Lorne Christopherson of Weldon (1 field), Dennis McIntosh of Melfort (2 fields), and Allan Moskal of Brooksby (1 field). Each cooperator had equipment available that would enable on-farm testing. All three were equipped with yield mapping equipment; Lorne and Allan used Greenstar™ and Dennis used Ag Leader™. All three were equipped with anhydrous ammonia rate controllers that were GPS compatible; Lorne and Allan had Raven™ and Dennis had Dickey John™. The farm cooperators were responsible for applying the nitrogen with their equipment and providing yield data of the results.

In 1999, the first year of the study, one field from each of the three cooperators was selected for soil sampling by Cargill to develop variable rate nitrogen prescriptions. Cargill's method of delineating management zones was to use panchromatic aerial photography and develop management zones using greyscale analysis. An example of their nitrogen prescription application map is illustrated in Figure 1 of Appendix B. Cargill shared no raw data; therefore the data could not be imported to SSToolbox for evaluation. A portable computer was used as a task controller for Allan Moskal and Lorne Christopherson and they both reported no issues with the equipment when applying the prescription. However, Cargill could not get their interface to work with the Dickey John™ controller of Dennis McIntosh. Because they could not resolve the issues, Dennis had to hire a third party consultant to get the equipment working in order to apply the prescription. Initially, each of the farmers reported that the arrangement with Cargill looked promising, but Cargill's initial contact person changed before the project was completed. Although the work was eventually finished, communication breakdowns

appear to have influenced the termination of the relationship. Also, the prescriptions did not work effectively in the farmer's mind, so Cargill was abandoned after 1999.

The soil sampling systems implemented in 1999 were 5 acre grid sampling and topographic sampling. Satellite imagery analysis was suggested as an alternative soil sampling system but consultation with experts from Alberta Agriculture and the University of Saskatchewan recommended that we avoid allocating time and resources to that method. Therefore, satellite imagery analysis was never used for soil sampling although it was purchased in 1999 to see if it could serve a useful purpose. Sampling from yield maps was never used either, but yield maps did serve a useful purpose in establishing topographic soil sampling points and for analyzing nitrogen response data. Benchmark sampling was previously suggested as well, but was never used.

The topographic and grid soil samples were analyzed for macronutrients, micronutrients, pH, and electrical conductivity (EC) in the initial year for each field. Micronutrients were not sampled every year due to cost restrictions. Unfortunately, organic matter was not analyzed in the first 2 years of the study.

No VRF applications were made in 2000 because no commercial service providers for management zoning procedures or variable rate prescriptions were available. NARF continued to soil sample all of the fields in 2000.

In 2001 revisions were made to the original application. Initially 3 farmers were cooperating but only Dennis McIntosh was able to provide NARF with a test-bed for VRF application. He had an implementation of VRF (called Pro-VRF) to apply variable rate nitrogen applications he had developed on his own. The two fields were removed from Allan Moskal and Lorne Christopherson to focus resources where they could be used effectively. NARF agreed that all resources should be focused on Dennis' fields as he had the only infrastructure in place to continue the investigations. NARF would continue to soil sample the initial 2 fields (NW 10 and SW 15) in the study at Dennis' and added a third (NW 26) to make up for the cooperator fields that were removed. Grid sampling continued on the NW 10 field.

Agrologist Cory Willness and Dennis McIntosh felt that the nitrogen recommendations and soil analytical methods currently used were not providing reliable

predictions of crop response to nitrogen fertilizer. Therefore further revisions were made to the protocol in 2001 to allow for testing of a new soil analytical method, the CMMAS test from Norwest Labs. It measures "potentially mineralizable nitrogen" and this provides an estimate of the nitrogen supplying power of the soil.

In 2001 the Pro-VRF method developed by Dennis McIntosh was used to apply VRF applications on the NW 10 site on his farm. Constant rate nitrogen and zero rate nitrogen strip trials were initiated to test the nitrogen fertilizer response and the appropriateness of the VRF prescriptions. The other two fields in the study had already received nitrogen applications the previous fall so they were unavailable for testing.

In 2002 the Pro-VRF method and the strip trial protocols were implemented in all 3 fields at Dennis' but severe weather events rendered the results useless.

It is important to note that Dennis McIntosh's cooperative efforts to accommodate this project work the last 2 years were very extensive and were all in-kind. Without his cooperation, this project would have shut down in 2000. The list of activities that he has performed for this project includes working with: anhydrous ammonia equipment, GPS receivers, GIS software, computer systems, task controllers, rate controllers, interface development, prescription rendering and development, yield monitoring and mapping, and more.

4. Results

Limited results are available from this project that meet our initial objectives. There were many disappointments that hindered any opportunity to obtain valid results. However, there were strong findings in certain facets of the research that were very exciting.

a) Precision Farming Service and Equipment Providers

Empty promises abound in the Precision Farming industry. Very few truly professional people exist that have the capabilities to deliver services at the level they say they will. It is an emerging industry that uses the latest technological advancements. There are often issues that need to be resolved and because very few people exist using

the technology to it's fullest extent, therefore the issues aren't being resolved at any great speed. Some of the problems we experienced with equipment and software interfaces have already been discussed. Two labs claimed to be able to provide us with soil test data that was directly importable to SSToolbox. When the smoke cleared neither was importable, and manual methods of importing soil test results were required. Basically, if a service provider can't provide you with the name of a client that is using his product or service, do not assume it will work. Unfortunately this business has been damaged by this problem and many of the early adopters are frustrated with the technology because of it.

Previous staff that setup this project had vastly underestimated the time, expertise, and resources necessary to complete the objectives for this type of work. One just has to count the number of successful VRF implementations in Canada and you will soon realize that service providers have not come up with a working solution. It is inconceivable that one can provide a detailed analysis of soil sampling systems for VRF when there is not a VRF implementation available. Furthermore, the degree of expertise required is extremely high. One would require experts in agronomy, geo-processing, GPS equipment, rate controllers, task controllers, geo-statistical analysis, and the list goes on. NARF, Cargill, and others just do not have the expertise in place to deliver results. Having said that, the Pro-VRF method implemented by cooperator Dennis McIntosh cannot be challenged because he has a full implementation of VRF on his farm. This fact alone puts him way out in front and it has assisted us with providing at least some results. Had 2002 been a decent crop year we would have had some pretty decent data.

b) Field Scale On-farm Trials in 1999 and 2000

Similar to the previous discussion, professionals break down on protocols for the design of valid on-farm trials. Plot designs and statistical methods are well established for small plot studies. However, ask a statistician how to design a field scale trial and he will tell you that you cannot get a valid result without randomization and replication. Very few experts exist on field scale studies.

For these reasons, the initial study design in this project was poor. The protocols in 1999 were to fertilize a one side of the field with a VRF nitrogen application and

compare the results to a constant rate nitrogen application on the other side. This protocol could never provide the anticipated results because there is no way to quantify the native variability that exists in the field with that design. Fields with significant levels of topographic variability will have huge yield variations between sides.

In 1999 no analysis of results is available because there are no results to analyze. The raw data files from Cargill's VRF applications were not made available to us. All that we have from the work is a nice picture of the VRF application on Christopherson's field, shown in Figure 1 of Appendix B. Even if the files were available they would be of limited value because there were no strip trials. Figures 2 and 3 of Appendix B illustrate the yield maps and soil sampling locations in the field at Christopherson's and Moskal's respectively. Christopherson was not able to provide a yield map for 1999.

No VRF applications were performed in 2000 but soil sampling continued. Appendix A contains the 1999 and 2000 soil sample data from Moskal's (Tables 1 and 2) and Christopherson's (Tables 3 and 4). At Moskal's there was a trend to higher nitrate levels in the depressions (mean= 44 lbs/ac) versus the knolls (mean=77 lbs/ac). There was no significant difference between nitrate levels on topographic sampling locations at Christopherson's. The grid samples from both sites have little value because they have no attributes to tell you what slope position they are on. Kriging could have been used to make a grid soil nitrate map, but with 5 acre grid sizes the results are useless. Most experts would recommend grid sampling to be 1 acre or less, which was totally cost prohibitive for this project and for dryland farmers in general.

Soil sample results from McIntosh's fields are in Tables 5,6,7 and 8 of Appendix A. They will be discussed further under heading c) as they were performed until 2002.

c) Field Scale On-farm Trials in 2001 and 2002

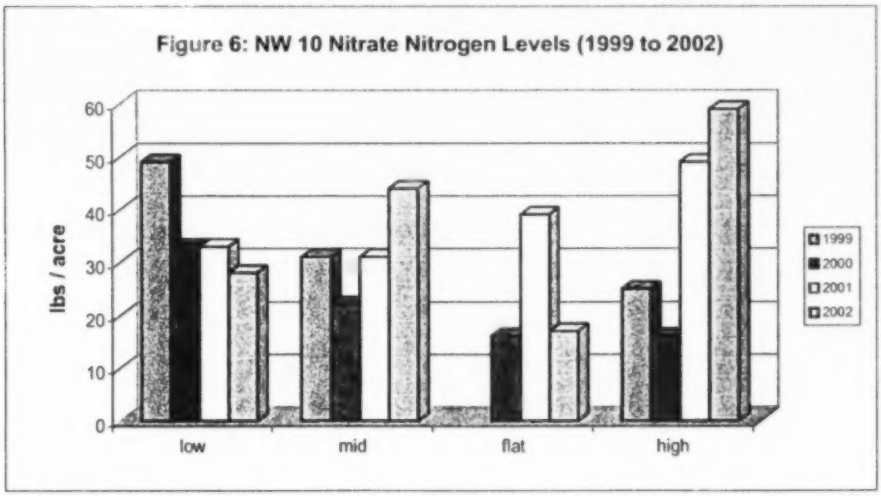
Field scale experiments on McIntosh's farm were well designed in the spring of 2001, although they were only put down in one field (NW 10 46 19 W2) because the other two fields in the study (SW 15 and NW 26) had already been fertilized with nitrogen in the fall of 2000. Therefore no results were gleaned from those fields in 2001. The results on NW 10 will be discussed thoroughly in this section.

In 2002 a severe drought occurred and yields in each of the 3 fields in the study were 10 bushels per acre or less. What crop was left from the drought suffered frost damage. To make matters worse combining was not finished until late November in extremely high moisture (ice and snow) conditions. As a result, the 2002 yield data is useless and was not even processed because of these issues.

The rest of the discussion under heading c) will be in reference to the 1999 work on the NW 10 46 19 W2 field. The trials from the NW 10 field where VRF prescriptions were applied are illustrated in Figure 2 of Appendix B. 70 pounds of actual nitrogen per acre were applied in the constant rate nitrogen strip trial. A zero nitrogen strip trial was also included. Barley was seeded with a seed-placed blend of 11-25-10-8 on the entire field. Figure 3 of Appendix B shows the 2001 yield map. 2001 was a very dry year and slightly below 3 inches of precipitation during the growing season was measured by a remote weather station in the field.

Figure 6 illustrates the change in nitrate levels that occurred under VRF over the 4 years of the study.

Figure 6: NW 10 Nitrate Nitrogen Levels (1999 to 2002)



Dennis' previous experience in his fields from average moisture years was that the response to nitrogen fertilizer was high on the knolls and low in the depressions. For this reason his prescriptions were to apply higher rates of N on the knolls and lighter rates

in the depressions. The trend in the depressions is that nitrates have been reduced initially and have since been static. Conversely, they have increased significantly on the knolls due to the high application rates of nitrogen under drought conditions. Although the data set is limited, one can visualize how a VRF application can be used to minimize nitrate levels in depressional soils, where leaching and denitrification losses will likely be higher, and target a reduction in fertilizer applications if high nitrate levels show up. With nitrates reaching nearly 60 lbs per acre on a 0-12" sample, Dennis has the ability to cut back on the knolls in 2003.

A detailed analysis was done on the zero nitrogen strip trial. Organic nitrogen release (ONR) was calculated based on the crop uptake of nitrogen and the change in nitrate levels from the fall 2000 to the fall of 2001. Assumptions were:

i) 11 pounds of nitrogen seed-placed, 80% use efficiency

ii) organic nitrogen, 80% use efficiency

iii) nitrate-N converted from 0-12" to 0-24" sample by conversion factor of 1.5X (documented by other research on this site), 50% use efficiency

iv) crop uptake of nitrogen for barley is in the range of 1.2 to 1.5 pounds per bushel, very high protein levels prompted me to use a 1.4 conversion

The results are shown in Figure 7. The mean of the 9 sites showed that organic nitrogen release (ONR) accounted for 79% of the nitrogen, the seed-placed fertilizer accounted for 11%, and the nitrates accounted for 10%. Actual nitrogen uptake from organic sources ranged from 31 to 143 pounds of actual N. On the fourth "low" site in figure 7 (fourth from left) not only did organic N provide 68 pounds of N for crop uptake but it also built soil nitrate levels an additional 28 pounds. The release of nitrogen from these soils was astonishing, and residual nitrates were not a significant contributor to yield.

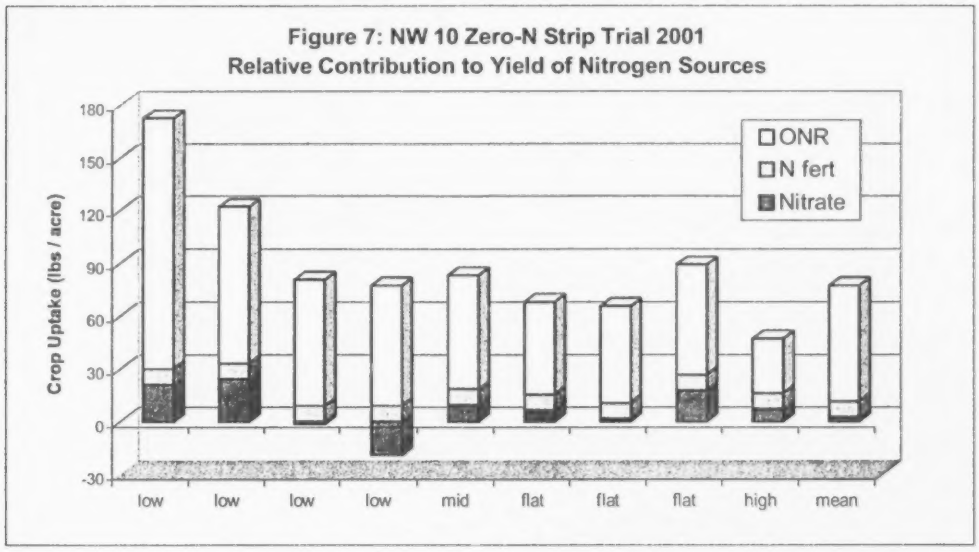


Figure 3 illustrates the results of the CMMAS test. This test has been standardized by 3rd party experts to give a more quantitative result for our research. The resulting ENR or "estimated nitrogen release" test results look promising. One can see how well the ENR test correlates with the ONR and yield.

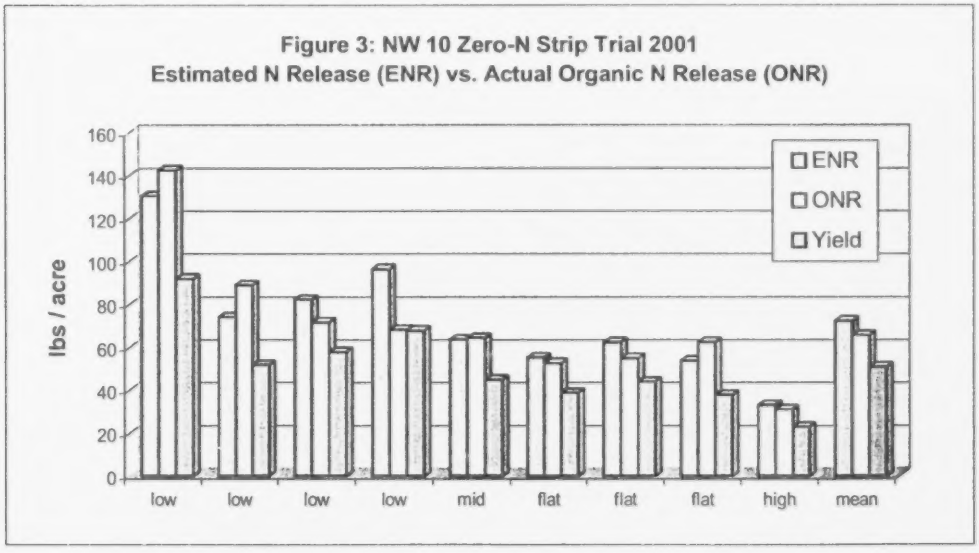
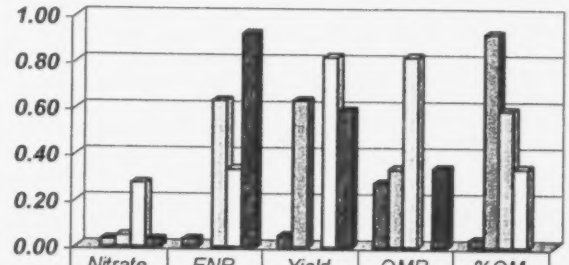


Figure 4 illustrates the R squared correlations for all of the data in the strip trial. Nitrates had no relationship with yield, ENR, or organic matter (%OM). ENR, OMR, and %OM had good correlations with yield, 0.63, 0.82, and 0.59 respectively. ENR and %OM had the highest correlation of 0.92.

Figure 4: Correlation Matrix for NW 10 Zero- Strip Trial 2001



	Nitrate	ENR	Yield	OMR	%OM
Nitrate		0.04	0.05	0.28	0.03
ENR	0.04		0.63	0.34	0.92
Yield	0.05	0.63		0.82	0.59
OMR	0.28	0.34	0.82		0.34
%OM	0.03	0.92	0.59	0.34	

The results of this trial illustrate three things: that field scale research can provide quality results if correctly designed, that under some conditions residual nitrates may not contribute as much to yield as many agronomists think, and that the new mineralizable N tests show considerable promise in answering some of the questions for nitrogen recommendations under VRF.

5. Conclusions

Precision farming in the prairies has been damaged by the empty promises of service and equipment providers. Commercial service providers of VRF implementations do not exist. Interfaces between many controllers and software are not available. In general, many farmers have invested in technology that has compatibility issues and may

never be able to perform the tasks they want. Very few experts exist that have a broad understanding of these issues.

Field scale on-farm research has taken on a new dimension. Field scale research in the past involved weigh wagons and plot designs that provided very low quality data. The introduction of GPS receivers to agriculture has allowed us to measure attributes of fields and record the location for future analysis. Integrated with equipment such as yield monitoring sensors, task controllers, rate controllers, and soil sampling data, it has allowed us to collect an immense amount of data every year on our fields. Using advanced GIS systems such as SSToolbox™ we are able to provide a very detailed analysis of our site specific investigations. The cost of this technology is very low relative to the amount of data that could be collected, but a very high level of expertise is required to put an entire program together that would provide valid results. As agronomic research funding from government subsides, it provides an excellent opportunity for farmers to step up and perform field scale research at a very low cost relative to small plot research.

We cannot make solid conclusions on our nitrogen fertility findings with our limited data set. However, the data does show that nitrogen fertilizer predictions based on soil nitrates can have considerable errors. It also shows that the level of nitrogen release from organic sources can be much higher than one would expect. The ENR test had a high correlation with yield and appears to mirror the actual organic nitrogen release well.

6. Indications for Further Development

Research and development is required on the new soil analytical techniques that measure the ability of the soil to release organic N by mineralization. If some of these procedures are proven to be reliable predictors of organic N mineralization, then existing soil test databases will need to be upgraded to integrate these measurements to provide improved nitrogen recommendations.

Extension to producers in Canada is required to inform them of the compatibility issues of equipment and software they purchase for precision farming applications on their farms. Even if farmers have the proper equipment and software, they would need to

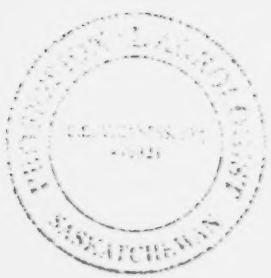
learn the limitations of it. It is not uncommon to see huge errors in data, rendering it useless. Experts in this area are rare and when a farmer such as Dennis McIntosh can put together the only complete farm implementation of VRF in western Canada it stands to reason we can learn a lot from him.

7. Extension, Innovation Fund Acknowledgement

AFIF acknowledgement is made at the AAFC Melfort Research Farm field day. AFIF is on the NARF sponsor signage on highway #6 across from the Melfort Research Farm. The NARF membership meets regularly and discusses ongoing project developments and acknowledges the contributions from AFIF regularly to its members. Once NARF has had ample time to digest the findings the board will make recommendations on releasing the findings of the project.

8. Personnel

Glenda Leach was the initial project manager in 1999. Cory Willness performed all of the technical work in the spring of 2001 and was appointed project manager by the NARF board in November of 2001 to see the project through to completion.



Cory Willness, P.Ag., CCA
January 29, 2003

Appendix A:
Soil Sampling Data

AFIF Project #98000166
"Precision Farming – NARF"
January 29, 2003

SW 3 48 17 W2
1999 to 2000 Soil Sampling Data**
Allan Moskal

Table 1: Topographical Soil Sampling Data

Point	Lat	Long	topo	pH	EC	N99	N00	P99	P00	K99	K00	S99	S00	Cu	Mn	Zn	B	Fe	Cl
1	53.106862	-104.415744	low	7.8	5.3	160	84	120	120	1200	1144	96	96	3.0	41.0	26.6	17.2	662	30
2	53.106452	-104.415357	high	8.0	0.7	31	31	9	13	616	544	96	42	2.2	12.0	1.0	3.8	90	23
3	53.104899	-104.414169	high	7.8	1.2	58	134	92	86	892	780	96	96	3.5	54.0	21.0	22.2	683	20
4	53.104432	-104.414110	low	8.0	0.7	50	54	51	47	620	524	96	96	2.3	23.0	8.7	16.2	227	31
5	53.105439	-104.411875	high	7.4	0.5	33	28	110	89	788	840	96	46	2.5	27.0	2.2	3.6	175	14
6	53.105829	-104.411652	low	7.7	0.5	31	134	9	86	756	780	58	96	2.2	15.0	0.9	2.7	87	24
7	53.107716	-104.410609	low	6.4	0.7	75	54	36	47	528	524	96	96	2.9	52.0	23.9	19.4	799	20
8	53.107693	-104.411179	high	7.6	0.5	34	22	21	25	584	480	67	47	2.2	14.0	1.1	3.8	125	18
9	53.108337	-104.411423	high	7.7	0.5	48	50	40	39	644	524	96	78	3.9	31.0	18.2	13.8	454	15
10	53.108337	-104.412349	low	6.4	0.7	75	58	36	92	528	892	96	96	2.9	52.0	23.9	19.4	799	17
11	53.109117	-104.413307	high	7.3	0.2	34	22	21	25	584	480	67	47	2.5	16.0	1.8	3.5	148	10
12	53.109152	-104.414589	low	7.8	0.7	48	50	40	39	644	524	96	78	3.4	16.0	8.8	12.4	337	14

Table 2: Grid Soil Sampling Data

Point	Lat	Long	grid	pH	EC	N99	N00	P99	P00	K99	K00	S99	S00	Cu	Mn	Zn	B	Fe	Cl
1	53.110247	-104.415375	grid	8.1	0.4	24	35	10	10	544	401	65	59	3.6	11.0	3.3	8.0	199	18
2	53.110247	-104.413401	grid	7.7	0.2	24	37	11	15	569	588	38	31	2.8	19.0	2.4	4.5	203	18
3	53.110244	-104.411435	grid	7.9	0.5	34	62	30	31	244	228	44	59	1.8	18.0	4.9	7.8	238	29
4	53.109060	-104.415373	grid	8.2	0.5	26	37	7	7	395	304	96	51	2.3	14.0	1.8	8.0	115	20
5	53.109062	-104.413404	grid	7.5	0.5	38	35	16	9	388	388	56	80	1.8	15.0	1.6	3.9	113	14
6	53.109063	-104.411431	grid	8.2	0.5	21	82	18	22	372	312	61	77	2.3	14.0	4.6	6.6	233	34
7	53.107884	-104.415371	grid	8.2	0.5	26	32	4	5	524	472	43	41	2.2	13.0	2.2	8.7	124	15
8	53.107856	-104.413370	grid	6.0	2.8	34	74	8	6	408	296	96	96	3.0	66.0	26.6	16.6	799	18
9	53.107880	-104.411433	grid	7.3	0.4	44	21	17	19	673	588	67	56	2.4	22.0	2.6	3.5	143	14
10	53.106699	-104.415381	grid	7.8	0.5	40	111	14	35	508	352	96	96	3.3	10.0	4.5	7.6	193	54
11	53.106696	-104.413408	grid	8.3	0.2	19	30	4	5	691	740	27	36	2.2	12.0	1.3	4.4	109	17
12	53.106697	-104.411438	grid	8.3	0.2	29	34	4	4	575	624	47	39	2.9	13.0	1.4	4.1	82	18
13	53.105515	-104.415373	grid	7.9	0.5	36	68	37	98	616	472	96	96	4.0	22.0	15.2	9.2	430	26
14	53.105516	-104.413404	grid	7.5	0.5	37	26	5	5	692	540	54	34	2.7	22.0	1.9	4.2	114	10
15	53.105516	-104.411428	grid	8.3	0.7	37	46	4	6	444	492	57	42	2.6	14.0	2.3	8.6	170	34
16	53.104332	-104.415371	grid	8.3	0.7	40	138	4	120	480	1200	86	96	2.4	14.0	1.8	7.7	136	88
17	53.104334	-104.411436	grid	8.1	0.9	75	70	120	12	1200	480	96	96	4.7	25.0	13.8	13.7	392	41

* all soil sample data is from a 0-12" depth

NE 31 42 22 W2
1999 to 2000 Soil Sampling Data**
Lorne Christopherson

Table 3: Topographical Soil Sampling Data

Point	Lat	Long	topo	pH	EC	N99	N00	P99	P00	K99	K00	S99	S00	Cu	Mn	Zn	B	Fe	Cl
1	52.972112	-105.196896	high	7.9	0.4	53	37	61	65	916	1022	56	45	2.3	14	2.8	7.1	88	26
2	52.973397	-105.200008	low	7.4	0.4	60	33	86	82	1200	1080	76	45	2.9	26	8.2	7.2	168	17
3	52.973003	-105.203077	high	7.5	0.5	65	47	26	28	888	1012	70	57	2.1	26	5.3	6.7	119	30
4	52.972343	-105.202325	low	6.9	0.4	98	55	102	108	816	698	96	76	3.8	40	11.5	13.0	686	17
5	52.971001	-105.204723	high	7.2	0.7	90	60	47	44	775	853	38	53	4.8	35	4.8	4.4	233	12
6	52.970892	-105.205293	low	6.5	0.4	73	61	102	102	1020	1020	55	53	4.9	56	17.3	4.3	679	19
7	52.971233	-105.206107	high	6.9	0.0	29	n/a	33	n/a	741	n/a	33	n/a	2.9	43	4.2	5.4	197	23
8	52.971695	-105.206914	low	6.6	0.0	36	n/a	108	n/a	1080	n/a	45	n/a	4.0	57	8.6	4.1	719	34

Table 4: Grid Soil Sampling Data

Point	Lat	Long	grid	pH	EC	N99	N00	P99	P00	K99	K00	S99	S00	Cu	Mn	Zn	B	Fe	Cl
1	52.973375	-105.206269	grid	7.3	0.2	54	37	37	27	812	828	74	48	2.2	28	7.6	7.2	156	36
2	52.973382	-105.204301	grid	6.8	0.2	50	50	19	19	716	864	62	58	2.5	50	9.7	6.4	302	19
3	52.973377	-105.202371	grid	6.6	0.5	66	43	79	98	1044	1064	75	64	2.8	47	19.8	7.6	530	15
4	52.973372	-105.200374	grid	7.6	0.5	54	35	30	17	932	832	51	45	4.1	27	5.7	8.5	202	16
5	52.973376	-105.198412	grid	6.8	0.2	33	30	37	21	892	819	38	31	4.3	54	2.8	4.3	212	12
6	52.973379	-105.196404	grid	7.5	0.2	26	26	23	19	819	785	31	34	4.4	27	3.0	3.7	135	8
7	52.972193	-105.206263	grid	7.7	0.5	46	39	40	34	832	768	59	87	2.2	26	7.9	7.6	187	41
8	52.972194	-105.204306	grid	7.2	0.2	37	25	34	33	1200	1080	52	37	3.8	37	3.5	4.8	259	12
9	52.972197	-105.202340	grid	7.1	0.4	42	44	23	42	886	965	63	65	4.8	21	4.5	10.2	258	27
10	52.972193	-105.200367	grid	6.8	0.2	58	34	35	31	1080	1076	62	40	3.8	48	10.3	8.9	307	30
11	52.972193	-105.198408	grid	6.8	0.2	65	40	89	76	1172	1004	70	50	3.7	45	9.3	6.8	337	40
12	52.972155	-105.196427	grid	6.9	0.2	57	50	73	51	852	965	75	45	3.0	55	6.1	7.3	293	24
13	52.971011	-105.206277	grid	7.8	0.5	39	42	22	21	784	760	46	33	2.6	14	2.5	6.4	92	12
14	52.971010	-105.204298	grid	7.5	0.4	44	42	15	24	695	857	47	37	4.8	26	3.5	4.2	198	8
15	52.971010	-105.202329	grid	6.9	0.2	33	28	27	18	713	778	49	70	2.9	38	9.0	8.6	295	35
16	52.971017	-105.200367	grid	6.5	0.2	62	54	30	31	688	1044	65	66	2.8	50	6.5	8.7	343	46
17	52.971010	-105.198413	grid	6.8	0.5	56	45	63	62	820	1092	56	54	2.7	53	11.6	8.3	353	18
18	52.971013	-105.197446	grid	6.7	0.2	40	50	38	36	821	1080	48	47	3.4	37	6.4	6.8	382	37

* all soil sample data is from a 0-12" depth

NW 10 46 19 W2
1999 to 2002 Soil Sampling Data**
Dennis McIntosh

Table 5: Topographical Soil Sampling Data

Point	Lat	Long	Topo	OM*	ENR*	pH	EC	N99	N00	N01	N02	P99	P00	P01	P02	K99	K00	K01	K02	S99	S00	S01	S02	Cu	Mn	Zn	B	Fe	Cl
1	52.9568300	-104.6879770	low	5.8	66	6.9	0.4	63	41	20	18	102	102	138	106	1020	1020	2420	1200	82	78	87	40	8.5	33	9.7	4.9	679	10
2	52.9570320	-104.6879700	mid	5.2	60	7.0	0.4	38	37	68	66	28	35	46	34	1020	1020	1368	644	79	82	49	40	7.5	33	3.1	5.4	220	14
3	52.9573840	-104.6880560	high	4.1	53	7.3	0.6	37	37	94	128	14	17	21	14	1020	1020	1048	568	53	49	32	30	8.4	22	1.8	5.2	160	14
4	52.9574910	-104.6808640	high	3.4	43	7.7	0.8	18	17	14	60	7	5	8	8	904	877	980	524	39	48	25	28	5.4	13	1.2	4.6	99	14
5	52.9574580	-104.6804840	mid	3.9	46	6.8	0.4	24	21	10	10	8	11	18	8	1020	911	1284	562	51	39	17	20	6.7	34	1.7	5.7	199	12
6	52.9574570	-104.6801180	low	6.0	66	7.5	0.6	40	33	16	32	24	19	23	26	1020	1020	2228	1200	61	63	47	40	5.9	23	9.0	8.2	299	12
7	52.9559130	-104.6809100	low	5.8	67	6.5	0.4	44	42	34	44	102	102	203	74	1020	1020	3056	1200	74	82	117	24	6.5	58	27.3	7.5	679	14
8	52.9557070	-104.6816860	mid	6.0	67	6.5	0.4	32	23	26	16	29	21	22	20	1020	1020	1108	762	41	62	28	22	3.4	50	9.1	9.2	290	18
9	52.9555900	-104.6822270	high	3.2	34	6.8	0.4	20	16	82	24	7	4	14	6	877	894	908	460	37	41	17	16	6.5	10	1.3	4.5	92	32
10	52.9535944	-104.6812508	high	2.4	24	8.4	0.7	n/a	6	44	58	n/a	6	7	20	n/a	502	828	610	n/a	10	26	26	3.2	8	0.6	2.8	50	18
11	52.9535184	-104.6815000	mid	5.5	64	7.4	1.0	n/a	18	50	76	n/a	8	18	18	n/a	678	1376	690	n/a	10	34	22	2.8	20	1.2	2.8	78	24
12	52.9534594	-104.6817678	low	6.4	79	7.0	0.5	n/a	28	32	32	n/a	10	33	18	n/a	742	1372	666	n/a	18	29	16	3.0	30	4.0	3.6	166	26
13	52.9534642	-104.6809220	high	3.3	36	7.8	0.8	n/a	12	38	28	n/a	6	19	8	n/a	658	1200	460	n/a	40	26	16	2.8	14	1.0	2.0	50	24
14	52.9534054	-104.6807602	mid	5.0	49	7.8	0.7	n/a	20	20	16	n/a	26	23	16	n/a	1200	1940	1200	n/a	26	30	14	2.0	22	2.6	2.2	64	34
15	52.9533210	-104.6805460	low	6.2	70	7.1	0.4	n/a	30	26	26	n/a	32	53	38	n/a	998	1796	1126	n/a	12	24	18	2.4	30	5.0	3.4	150	26
16	52.9524512	-104.6790788	flat	5.8	70	7.3	0.4	n/a	24	24	16	n/a	16	26	18	n/a	732	1180	598	n/a	18	18	28	2.0	26	3.0	2.6	110	34
17	52.9515042	-104.6775860	flat	5.3	57	7.5	1.0	n/a	16	18	24	n/a	10	13	20	n/a	746	1152	744	n/a	18	28	28	6.0	18	6.2	2.0	114	30
18	52.9513988	-104.6808458	flat	4.9	57	7.4	1.0	n/a	12	24	18	n/a	8	24	14	n/a	716	1420	602	n/a	10	23	16	6.4	18	5.6	2.2	124	26
19	52.9521844	-104.6844166	high	4.6	52	7.8	0.8	n/a	16	50	36	n/a	6	14	16	n/a	600	1092	734	n/a	10	24	26	3.0	16	0.8	2.0	74	32
20	52.9521184	-104.6846562	mid	5.8	60	8.2	0.7	n/a	18	28	56	n/a	8	12	20	n/a	720	1092	706	n/a	12	14	32	4.8	26	5.4	2.8	88	28
21	52.9520596	-104.6848668	low	5.7	65	7.5	0.9	n/a	48	50	30	n/a	14	23	22	n/a	1070	1348	880	n/a	20	24	36	5.6	26	8.6	3.8	176	28
22	52.9546716	-104.6857762	flat	5.9	74	7.8	0.8	n/a	14	52	18	n/a	14	18	26	n/a	754	1248	674	n/a	18	30	20	6.0	18	6.0	2.4	162	26
23	52.9548998	-104.6847190	flat	4.3	56	7.8	1.1	n/a	14	70	12	n/a	8	15	14	n/a	750	1312	576	n/a	10	45	24	5.0	18	5.8	2.4	100	24
24	52.9543430	-104.6832804	flat	5.9	66	7.2	0.6	n/a	18	46	14	n/a	16	42	28	n/a	884	2464	806	n/a	12	45	20	4.8	14	1.8	1.8	200	30
25	52.9557006	-104.6782078	high	2.9	26	7.1	0.7	n/a	10	18	76	n/a	6	29	8	n/a	562	1612	460	n/a	8	40	28	2.8	12	0.8	2.2	48	30
26	52.9557974	-104.6783854	mid	4.2	38	7.0	0.7	n/a	16	12	68	n/a	10	27	12	n/a	710	1836	624	n/a	16	53	34	5.6	20	4.6	2.0	78	28
27	52.9559338	-104.6786238	low	5.6	50	6.4	0.5	n/a	12	54	12	n/a	8	58	20	n/a	652	1864	550	n/a	18	33	20	3.8	18	1.4	5.2	70	24

* OM (organic matter) and ENR (estimated nitrogen release) samples are both taken at a 0-6" depth

**all other soil characteristics are taken at a 0-12" depth

Prepared by Cory Willness

NW 10 46 19 W2
1999 to 2002 Soil Sampling Data**
Dennis McIntosh

Table 6: Grid Soil Sampling Data

Point	Lat	Long	pH	EC	OM*	ENR*	N99	N00	N01	N02	P99	P00	P01	P02	K99	K00	K01	K02	S99	S00	S01	S02	Cu	Mn	Zn	B	Fe	Cl
1	52.957248	-104.686631	7.6	0.8	2.5	39	20	14	6	10	7	10	20	8	1020	1020	640	893	50	31	36	28	7.8	16	1.8	7.0	180	10
2	52.957248	-104.684741	7.1	0.6	4.3	59	32	21	12	15	74	27	66	24	1020	1020	900	980	55	69	52	64	4.7	26	10.7	7.3	530	20
3	52.957248	-104.682851	7.5	0.6	4.0	53	20	18	10	14	13	16	22	14	1020	1020	1200	1080	33	33	50	34	5.0	27	1.6	6.2	144	26
4	52.957248	-104.680960	6.6	0.4	4.8	69	27	22	10	17	24	22	36	18	1020	1020	760	933	49	35	40	32	5.4	41	4.8	6.6	364	10
5	52.957248	-104.679070	6.8	0.6	4.0	48	35	35	14	22	39	38	44	32	1020	1020	704	915	77	59	44	52	5.6	26	6.0	7.5	574	12
6	52.957248	-104.677180	6.8	0.6	3.4	46	33	20	10	12	37	61	36	49	1020	1020	900	980	46	39	32	30	6.0	34	8.9	7.5	367	22
7	52.956109	-104.686631	7.5	0.6	3.6	55	18	27	12	14	14	14	22	12	1020	1020	934	991	43	52	22	44	6.5	21	2.6	5.2	159	12
8	52.956109	-104.684741	6.8	0.6	4.5	62	24	20	10	8	102	102	72	88	1020	1020	1200	1080	49	35	34	32	5.6	37	24.3	6.0	679	14
9	52.956109	-104.682851	6.7	0.6	4.7	69	34	29	14	12	85	102	36	87	1020	1020	1200	1080	46	44	20	40	5.2	48	13.5	7.6	616	8
10	52.956109	-104.680960	6.7	0.6	5.4	76	46	35	22	14	99	91	68	73	1020	1020	1200	1080	75	54	40	49	5.6	56	21.4	8.0	679	12
11	52.956109	-104.679070	8.1	0.8	3.1	46	29	17	32	20	18	17	24	18	1020	1020	1200	1080	56	36	38	32	7.2	15	3.7	5.2	177	12
12	52.956109	-104.677180	7.2	1.1	4.4	55	37	27	12	10	102	102	128	90	1020	1020	728	923	45	32	18	30	4.3	41	21.5	6.0	679	10
13	52.954970	-104.686631	6.8	0.4	3.7	55	38	24	10	14	102	102	120	88	1020	1020	674	905	48	45	24	41	5.0	32	7.6	4.1	679	8
14	52.954970	-104.684741	6.8	0.6	3.9	53	33	34	14	12	35	30	32	24	1020	1020	624	888	39	34	36	28	5.6	40	8.6	7.3	360	14
15	52.954970	-104.682851	7.0	0.6	6.2	71	33	31	18	16	43	37	48	30	1020	1020	844	961	44	36	54	36	4.6	27	11.6	7.2	290	28
16	52.954970	-104.680960	7.0	0.4	5.2	69	33	37	22	20	21	17	26	20	1020	1020	796	945	40	45	58	41	5.7	53	12.2	9.2	432	24
17	52.954970	-104.679070	6.9	0.4	4.7	61	59	49	20	18	62	75	50	60	1020	1020	964	1001	82	82	40	70	7.8	31	8.0	8.8	569	14
18	52.954970	-104.677180	6.5	0.4	4.2	55	32	35	10	12	22	22	22	20	1020	1020	840	788	51	71	22	56	6.6	41	5.7	8.2	256	10

* OM (organic matter) and ENR (estimated nitrogen release) samples are both taken at a 0-6" depth
**all other soil characteristics are taken at a 0-12" depth

Prepared by Cory Willness

SW 15 46 19 W2
1999 to 2002 Soil Sampling Data**
Dennis McIntosh

Table 7: Topographical Soil Sampling Data

Point	Lat	Long	Topo	OM*	ENR*	pH	EC	N99	N00	N01	N02	P99	P00	P01	P02	K99	K00	K01	K02	S99	S00	S01	S02	Cu	Mn	Zn	B	Fe	Cl
1	52.9589920	-104.684713	low	6.1	68	7.6	1.2	34	44	16	30	27	18	16	34	819	898	1312	704	48	54	200	24	3.9	55	10.9	8.6	355	20
2	52.9589940	-104.685011	mid	5.6	65	7.4	0.8	29	31	10	30	26	10	10	24	911	952	1260	728	40	62	68	20	4.6	78	7.7	7.5	340	14
3	52.9590100	-104.685568	high	4.5	54	6.9	0.4	15	31	10	32	16	12	12	16	952	1020	1268	684	30	35	34	24	6.2	36	9.7	5.2	388	12
4	52.9605500	-104.685027	low	5.5	61	8.1	1.2	56	34	18	76	49	51	22	120	1020	1020	1972	900	78	82	200	40	6.2	19	5.4	4.9	397	14
5	52.9607630	-104.684995	mid	3.6	47	8.3	0.8	74	83	16	62	43	89	12	120	1040	1020	1024	674	51	78	50	34	3.4	30	11.2	7.8	134	22
6	52.9610280	-104.685015	high	2.8	26	8.3	0.7	20	21	18	60	7	3	14	18	605	683	876	586	56	52	38	24	6.4	10	1.0	4.0	89	46
7	52.9612800	-104.684994	mid	3.9	37	7.9	0.7	17	22	8	44	9	4	8	32	751	887	1232	624	27	58	30	28	6.8	22	1.4	4.1	118	16
8	52.9614790	-104.685002	low	5.7	60	7.7	0.7	43	33	16	36	32	36	36	40	1020	898	1356	934	37	39	96	34	4.6	45	7.8	6.9	388	14
9	52.9608570	-104.684187	low	5.7	65	7.6	0.8	29	32	22	46	62	59	48	64	1020	1020	2688	1200	54	53	110	36	5.6	35	10.8	8.0	506	14
10	52.9609210	-104.683950	mid	4.9	57	7.7	1.0	30	27	14	118	21	12	12	28	1020	1020	1164	844	47	44	62	34	6.0	50	6.1	7.5	265	18
11	52.9610630	-104.683584	high	3.3	33	7.9	0.8	25	17	42	64	7	3	30	10	666	785	1016	640	31	44	82	34	5.5	11	1.1	5.6	88	16
12	52.9627310	-104.685130	low	5.4	56	7.6	1.0	41	52	30	66	45	71	54	62	1020	1020	2436	1200	64	75	200	40	6.7	32	20.4	10.5	579	22
13	52.9628860	-104.684902	mid	4.7	53	7.7	1.0	21	33	12	28	13	15	14	18	1020	1020	1380	796	44	51	68	28	5.8	39	3.2	8.0	203	18
14	52.9631480	-104.684583	high	4.2	46	7.8	1.0	41	31	30	56	19	6	14	18	1020	1020	1556	900	38	41	86	28	6.5	50	4.8	6.7	288	10
15	52.9630390	-104.686484	low	6.7	85	7.1	1.0	72	67	48	74	108	91	112	98	1080	1020	2224	1200	47	59	200	34	4.8	61	27.7	9.4	582	26
16	52.9631610	-104.686859	mid	6.0	78	7.3	0.9	50	35	22	62	30	15	22	32	949	962	1548	964	44	54	66	26	3.8	85	7.5	9.5	299	24
17	52.9633880	-104.687408	high	4.0	44	7.8	0.7	28	20	18	78	28	12	14	28	1020	1020	1444	1200	35	50	30	28	7.8	29	3.6	5.0	161	14
18	52.9595142	-104.678745	flat	6.2	75	6.7	0.6	n/a	30	30	32	n/a	6	26	30	n/a	770	1880	1200	n/a	22	92	20	5.8	12	6.4	2.0	88	14
19	52.9604514	-104.680812	flat	5.1	62	7.5	1.0	n/a	44	18	48	n/a	18	16	20	n/a	650	1376	796	n/a	12	88	32	2.8	15	3.6	4.2	86	22
20	52.9614544	-104.681964	flat	6.0	66	7.2	1.0	n/a	48	18	40	n/a	20	20	48	n/a	760	1420	970	n/a	10	64	24	3.6	13	2.2	2.6	141	18
21	52.9600846	-104.682471	flat	5.4	52	7.5	1.1	n/a	44	10	54	n/a	14	16	40	n/a	644	1112	932	n/a	12	84	26	2.8	12	2.4	3.0	87	16
22	52.9591328	-104.686432	flat	5.3	56	7.3	1.1	n/a	44	64	42	n/a	10	16	16	n/a	856	1692	1066	n/a	12	70	24	3.6	11	1.4	2.6	75	23
23	52.9609694	-104.687122	flat	5.0	52	6.6	0.5	n/a	58	28	62	n/a	10	18	32	n/a	694	1504	852	n/a	12	76	26	5.0	10	2.8	2.6	199	14
24	52.9634744	-104.684495	flat	5.4	56	7.5	1.0	n/a	28	14	124	n/a	8	14	18	n/a	758	1540	864	n/a	8	50	32	3.8	11	1.6	3.0	78	18
25	52.9625446	-104.686168	low	6.2	60	7.6	1.1	n/a	52	24	40	n/a	8	24	20	n/a	988	1992	1200	n/a	40	86	40	5.0	9	3.0	3.2	60	22
26	52.9621650	-104.686444	mid	4.4	46	7.1	0.4	n/a	26	16	40	n/a	10	22	22	n/a	702	1440	840	n/a	12	20	16	3.8	11	1.6	3.4	81	19
27	52.9619936	-104.686575	high	3.6	33	7.6	0.9	n/a	16	36	44	n/a	6	14	12	n/a	600	1288	760	n/a	10	50	32	5.4	6	4.4	2.6	28	16

* OM (organic matter) and ENR (estimated nitrogen release) samples are both taken at a 0-6" depth

**all other soil characteristics are taken at a 0-12" depth

Prepared by Cory Willness

NW 26 46 18 W2
1999 to 2002 Soil Sampling Data**
Dennis McIntosh

Table 8: Topographical Soil Sampling Data

Point	Lat	Long	topo	pH	EC	OM*	ENR*	N00	N01	N02	P00	P01	P02	K00	K01	K02	S00	S01	S02	Cu	Mn	Zn	B	Fe	Cl
1	52.9971680	-104.5136358	flat	7.0	0.9	6.0	65	12	45	52	14	11	60	682	642	1130	17	36	28	3.0	14.2	3.2	2.2	164	72
2	52.9978646	-104.5135878	flat	6.6	0.4	6.6	88	20	33	28	12	17	36	616	700	634	11	8	24	3.6	19.6	5.0	2.2	244	44
3	52.9988386	-104.5148318	low	6.6	0.5	6.1	70	34	8	42	36	9	94	790	580	1200	7	30	26	2.4	15.8	5.2	3.2	434	48
4	52.9989168	-104.5152970	high	7.2	1.3	5.4	59	16	29	28	10	9	36	568	498	760	15	30	22	3.4	15.8	1.6	3.4	118	52
5	52.9991898	-104.5160866	low	6.4	0.6	5.9	62	26	9	30	64	34	86	646	676	802	12	18	28	2.4	9.4	8.6	2.0	628	42
6	52.9981204	-104.5171912	flat	6.7	0.5	5.7	61	24	23	26	10	14	26	474	478	630	10	16	24	2.6	22.0	2.2	2.2	174	50
7	53.0010490	-104.5165112	flat	6.9	1.0	3.9	45	18	10	42	12	9	36	590	440	774	8	16	28	2.2	27.8	1.8	2.2	130	56
8	53.0007678	-104.5122954	flat	7.2	8.3	6.0	58	22	13	28	12	13	28	626	448	694	29	40	26	2.8	11.6	2.2	2.2	172	60
9	53.0009196	-104.5114294	low	5.9	0.7	5.7	76	72	50	56	118	76	116	1200	964	1200	18	32	40	5.2	20.2	11.6	3.2	708	36
10	53.0007710	-104.5099508	flat	7.0	1.0	5.7	52	12	9	26	20	12	26	536	400	570	9	16	26	2.4	18.4	2.0	2.4	168	44
11	53.0004654	-104.5099574	mid	7.0	1.4	6.3	61	18	13	34	12	12	42	614	530	828	100	40	38	2.6	11.6	2.8	2.2	176	44
12	52.9999294	-104.5106688	flat	6.9	1.2	6.0	63	24	25	30	14	23	26	602	562	654	20	40	30	1.4	8.8	1.4	2.2	78	62
13	52.9983662	-104.5087552	flat	6.9	1.1	5.8	61	16	8	40	8	11	38	450	482	858	15	22	24	2.4	15.2	1.8	2.0	192	42
14	52.9960156	-104.5079398	flat	6.8	1.3	6.2	71	18	13	40	22	13	28	552	514	702	26	40	26	3.4	17.0	2.4	1.8	202	74
15	52.9970444	-104.5076502	mid	6.6	1.2	6.1	74	36	8	30	14	9	24	540	488	614	21	36	20	2.6	21.4	3.8	2.4	312	56
16	52.9955500	-104.5079742	flat	6.6	0.5	5.9	67	10	26	24	8	9	24	456	492	624	9	8	30	3.4	15.2	2.0	1.6	254	36
17	52.9955478	-104.5095648	flat	5.8	0.2	5.2	62	26	8	34	58	46	100	526	540	664	6	14	28	3.6	7.6	5.8	1.4	598	38
18	52.9955130	-104.5106648	flat	6.7	0.4	6.2	72	16	18	30	12	12	24	514	562	630	10	22	28	3.2	15.2	4.0	2.0	262	40
19	52.9954458	-104.5134380	test	6.5	0.5	2.2	36	58	6	6	16	12	16	698	778	1056	8	20	16	9.0	15.2	1.8	1.6	254	54
20	52.9997256	-104.5176492	low	6.2	0.4	5.7	73	54	26	40	102	86	120	642	616	882	17	30	32	2.2	8.8	8.0	1.8	642	54

* OM (organic matter) and ENR (estimated nitrogen release) samples are both taken at a 0-6" depth
**all other soil characteristics are taken at a 0-12" depth

Appendix B:
Field Maps

AFIF Project #98000166
"Precision Farming – NARF"
January 29, 2003

Figure 1: Cargill Prescription Nitrogen Map for Lorne Christopherson's Field

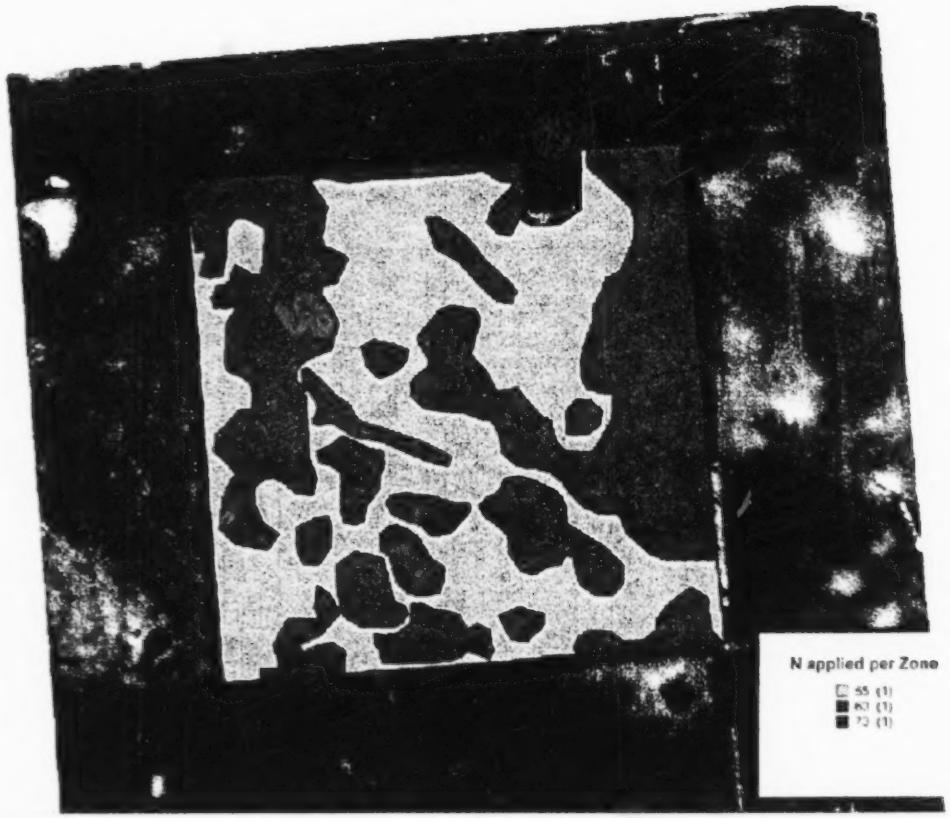


Figure 2:

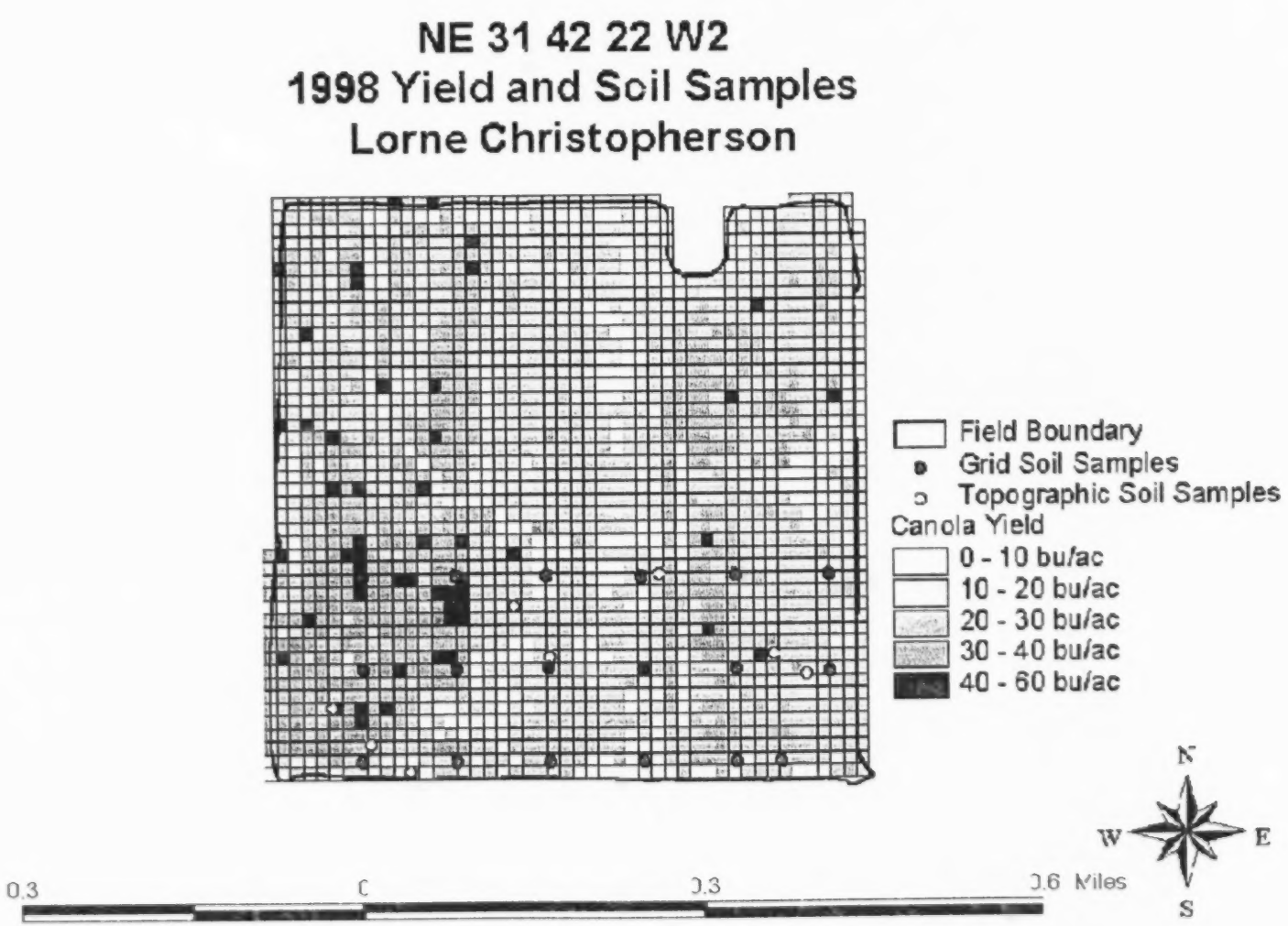

NE 31 42 22 W2
1998 Yield and Soil Samples
Lorne Christopherson
Field Boundary
Grid Soil Samples
Topographic Soil Samples
Canola Yield
0 - 10 bu/ac
10 - 20 bu/ac
20 - 30 bu/ac
30 - 40 bu/ac
40 - 60 bu/ac
N
W
E
S
0.3
0
0.3
0.6 Miles

Figure 3:

SW 3 48 17 W2
1999 Yield and Soil Samples
Allan Moskal

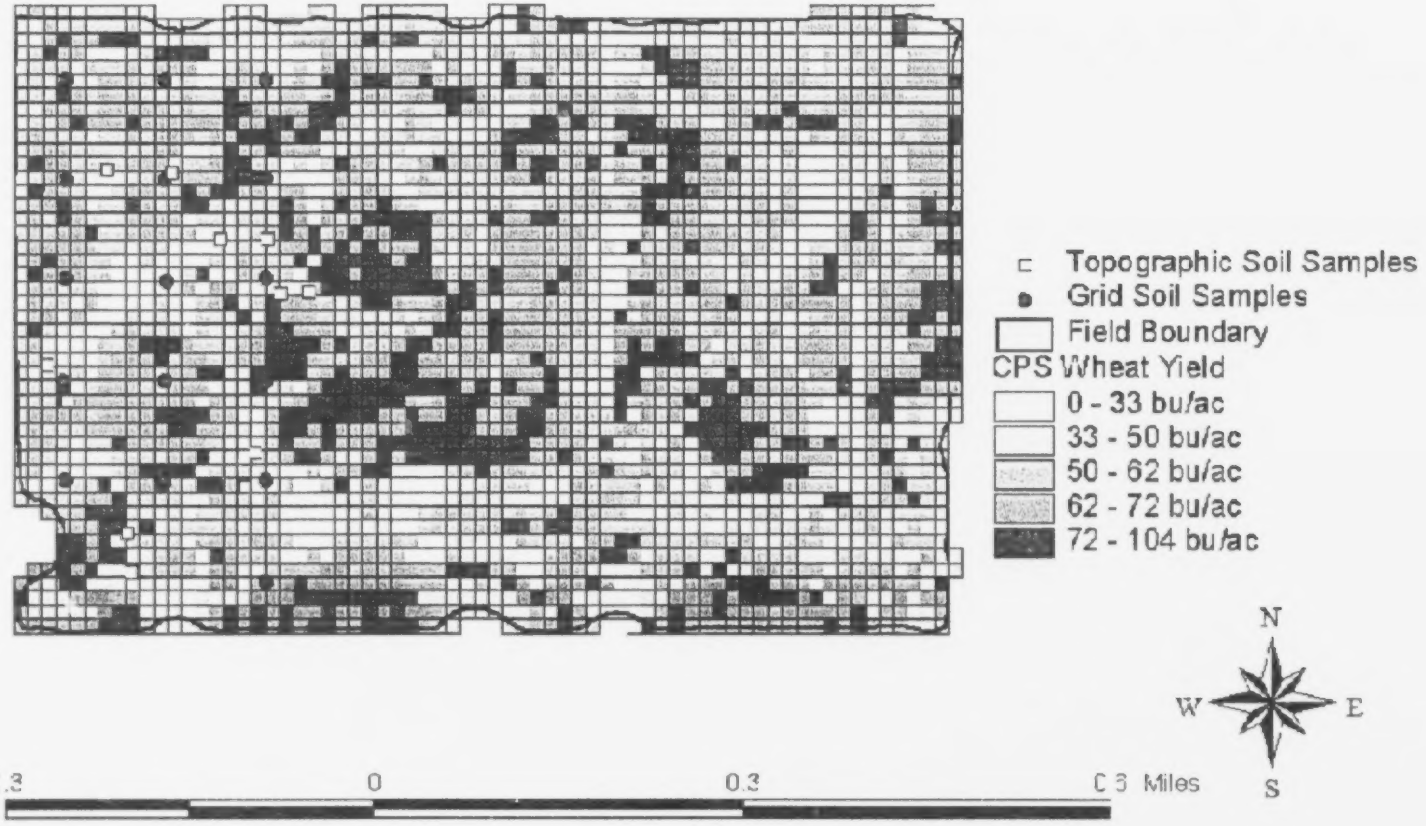


Figure 4:

NW 10 46 19 W2
2001 As-applied Nitrogen Prescription and Soil Samples
Dennis McIntosh

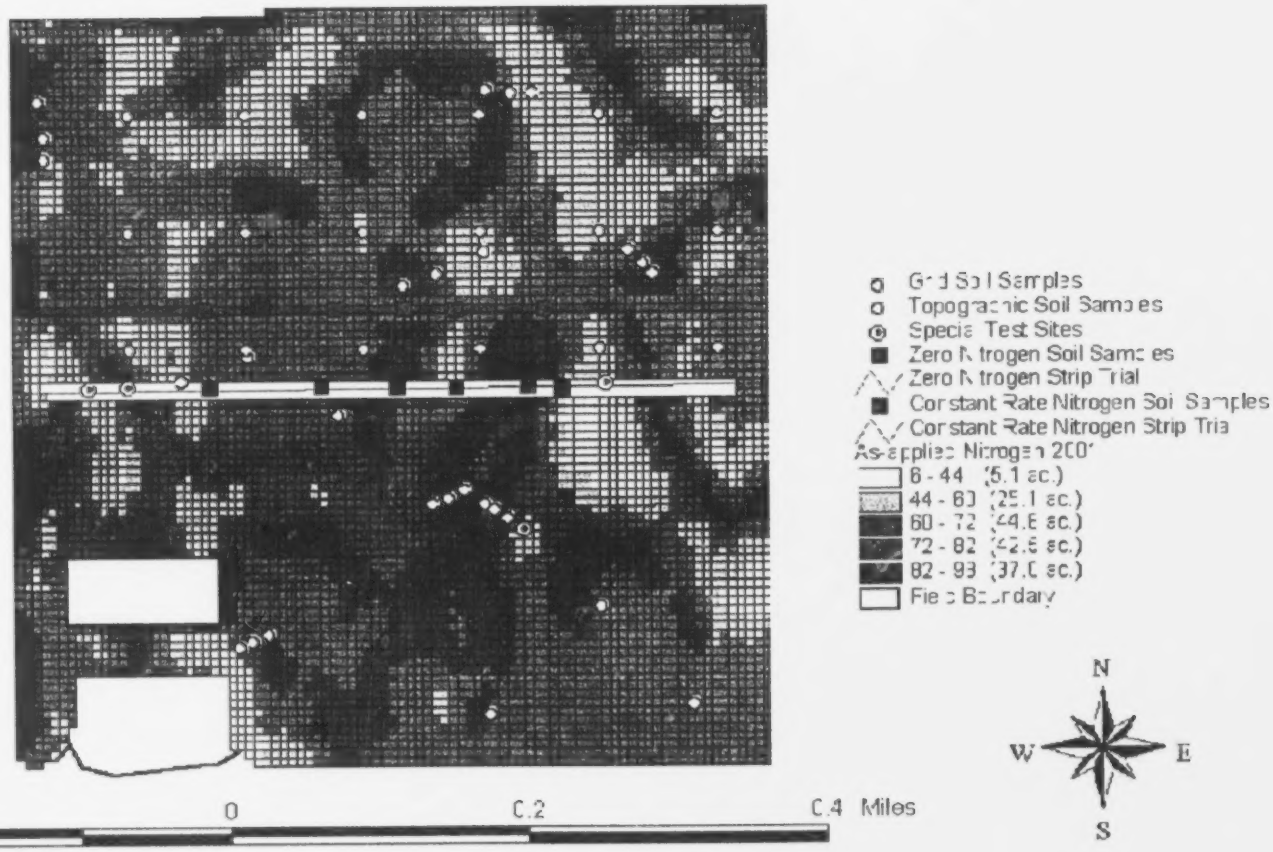
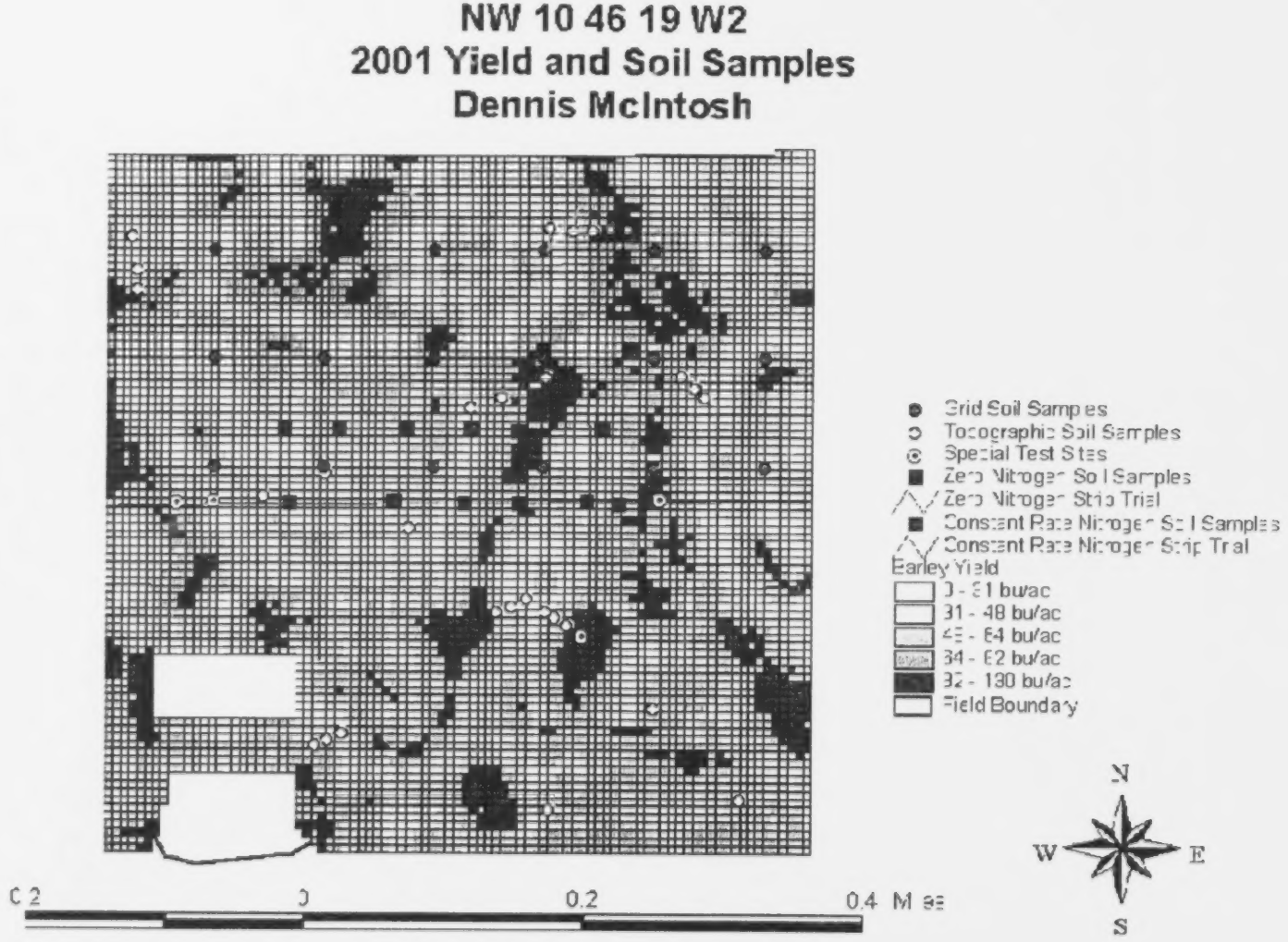


Figure 5:


NW 10 46 19 W2
2001 Yield and Soil Samples
Dennis McIntosh
Grid Soil Samples
Topographic Soil Samples
Special Test Sites
Zero Nitrogen Soil Samples
Zero Nitrogen Strip Trial
Constant Rate Nitrogen Soil Samples
Constant Rate Nitrogen Strip Trial
Barley Yield
0 - 31 bu/ac
31 - 48 bu/ac
48 - 64 bu/ac
64 - 82 bu/ac
82 - 130 bu/ac
Field Boundary
0.2
0
0.2
0.4 Miles
N
W
E
S